

CLAIMS

1. A method of estimating the location of a mobile device, comprising the steps of:

collecting location information;

selecting at least one of a plurality of different location methods to provide a location estimate said methods comprising using cell identity information; and

providing a location estimate based on the at least one selected location method.

2. A method as claimed in claim 1 wherein said at least one location method comprises the following methods:

a method using cell identity information;

a method using cell identity information and received signal strength;

a method using cell identity information and timing advance information; and

a method using cell identity information, received signal strength information and timing advance information.

3. A method as claimed in claim 1 or 2, comprising the step of determining a virtual base station estimate.

4. A method as claimed in claim 3 when appended to claim 2, wherein said virtual base station estimate is determined using at least one of the methods of claim 2.

5. A method as claimed in claim 3 or 4, wherein said virtual base station location estimate coupled with at least one virtual measurement and at least one real measurement and said at least one virtual measurement is processed using a location method.

6. A method as claimed in claim 5, wherein the at least one real and the at least one virtual measurements are processed using a location method as defined in claim 2.

7. A method as claimed in claim 5 or 6, wherein a value for the virtual measurement is one of measured levels, a combination of measured levels, and an average of measured levels.

8. A method as claimed in any preceding claim, wherein said at least one location method is selected in dependence on the location information available.

9. A method as claimed in any preceding claim, wherein a plurality of location estimates are determined and at least one estimate is used to provide said location estimate.

10. A method as claimed in any preceding claim, wherein said location information is collected by said mobile device.

11. A method as claimed in claim 10, wherein said mobile device is arranged to measure a level of at least one type of information.

12. A method as claimed in any preceding claim, wherein said location information comprises at least one of timing advance information and received signal level.

13. A method as claimed in claim 12, wherein said received signal level is an absolute received signal level or relative received signal level.

14. A method as claimed in any preceding claim, wherein said mobile device is in a cellular communications device.

15. A method as claimed in claim 14, wherein said information is collected for a serving cell of the mobile device.

16. A method as claimed in claim 14 or 154, wherein said information is collected for at least one neighbouring cell.

17. A method as claimed in any of claims 14 to 16, comprising the step of selecting the or each cell in respect of which location information is collected.

18. A method as claimed in any preceding claim, wherein a location estimate is provided using the following algorithm

Calculate the total attenuation experienced by a signal transmitted by the i-th BTS while propagating toward a mobile station where i-th level observation is L^i) by subtracting from the i-th measured received power, P^i_r, the maximum power radiated by the i-th BTS, $P^i_{t,max}$:

$$L^i = P^i_r - P^i_{t,max} \quad ; \quad i = 1, \ldots, N \qquad (11)$$

Stack the level observations from N BTS's in vector **L**:

$$\mathbf{L} = \left[L^1, \ldots, L^N\right]^T \qquad (12)$$

Solve the minimization problem:

$$\begin{bmatrix} \hat{\sigma_u}^2 \\ \hat{x} \\ \hat{y} \end{bmatrix} = \arg \min_{\begin{bmatrix} \sigma_u^2 \\ x \\ y \end{bmatrix}} F\left(x, y; \sigma_u^2\right) \qquad (13)$$

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where the *cost function* $F\ (x,y;\ \sigma_u^{\,2})$ is defined as follows:

$$F\left(x,y;\sigma_u{}^2\right) = \ln\sigma_u{}^2 + \ln\left|\mathbf{r_L}(x,y)\right| + \frac{1}{\sigma_u{}^2}\left[\mathbf{L}-\mathbf{m_L}(x,y)\right]^T \mathbf{r_L}^{-1}(x,y)\left[\mathbf{L}-\mathbf{m_L}(x,y)\right] \qquad (14)$$

and

$$\mathbf{m_L}(x,y) = \left[\mu_L^1(x,y),\ldots,\mu_L^N(x,y)\right]^T \qquad (15)$$

$$\mu_L^i(x,y) = -\mathrm{PL}^i\left(d^i(x,y)\right) - AP_{tr}^i\left(\psi^i(x,y)\right) \qquad (16)$$

$$\left[\mathbf{r_L}(x,y)\right]_{ij} = \begin{cases} 1 & i=j \\ \rho_u^{i,j}(x,y) & i\neq j \end{cases} \qquad i,j=1,\ldots,N \qquad (17)$$

19. A method as claimed in any preceding claim, wherein a location estimate is provided using the following algorithm

Calculate the total attenuation experienced by a signal transmitted by the i-th BTS while propagating toward a mobile station where the i-th level observation is L^i by subtracting from the i-th measured received power, P^i_r, the maximum power radiated by the i-th BTS, $P^i_{t,max}$:

$$L^i = P_r^i - P_{t,max}^i \quad ; \quad i=1,\ldots,N \qquad (18)$$

Stack level observations from *N* BTS's in vector **L**:

$$\mathbf{L} = \left[L^1,\ldots,L^N\right]^T \qquad (19)$$

Solve the minimization problem:

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$$\begin{bmatrix} \hat{x} \\ \hat{y} \end{bmatrix} = \arg \min_{\begin{bmatrix} x \\ y \end{bmatrix} \in \mathcal{D}_{xy}} F(x,y) \qquad (20)$$

where the *cost function* *F(x,y)* is defined as follows:

$$F(x,y) = \sum_{i=1}^{N} \left(L^i + \mathrm{PL}^i(x,y) + AP^i_{tr}(x,y) \right)^2 \qquad (21)$$

and D_{xy} is the domain of existence of x and y.

Calculate $\hat{\sigma}_u^2$ as

$$\hat{\sigma_u}^2 = F(\hat{x},\hat{y}) \qquad (22)$$

20. A method as claimed in any preceding claim, wherein a location estimate is provided using the following algorithm:

Calculate the total attenuation experienced by a signal transmitted by the i-th BTS while propagating toward a mobile station where the i-th *level observation* is L^i) by subtracting from the i-th *measured* received power, Pt, the maximum power radiated by the i-th BTS, $P^i_{t,max}$:

$$L^i = P^i_r - P^i_{t,max} \quad ; \quad i = 1, \ldots, N \qquad (23)$$

Calculate the j-th *level difference observation* by subtracting the j-th level observation from the level observation L^1 taken as reference:

$$D^j = L^1 - L^j \quad ; \quad j = 2, \ldots, N \qquad (24)$$

Stack the *N - 1* difference of level observations in a vector **D**:

$$\mathrm{D} = \left[D^2, \ldots, D^N \right]^T \qquad (25)$$

Solve the minimization problem

$$\begin{bmatrix} \hat{x} \\ \hat{y} \end{bmatrix} = \arg \min_{\begin{bmatrix} x \\ y \end{bmatrix} \in \mathcal{D}_{xy}} F(x,y) \tag{26}$$

where

$$F(x,y) = \sum_{j=2}^{N} \left(D^j - \mu_D^j(x,y)\right)^2 - \frac{1}{N}\left(\sum_{j=2}^{N} D^j - \mu_D^j(x,y)\right)^2 \tag{27}$$

and

$$\mu_D^j(x,y) = -\left[\mathrm{PL}^1\left(d^1(x,y)\right) - \mathrm{PL}^j\left(d^j(x,y)\right)\right] - \left[AP_{tr}^1\left(\psi^1(x,y)\right) - AP_{tr}^j\left(\psi^j(x,y)\right)\right] \tag{28}$$

D_{xy} is the domain of existence of x and y.

21. A method as claimed in any preceding claim, wherein a location estimate is provided using an algorithm solving the following equation in *x* and *y*:

$$\begin{cases} \sum_{i=1}^{N} F^i(x,y)\left(x - x^i\right) = 0 \\ \sum_{i=1}^{N} F^i(x,y)\left(y - y^i\right) = 0 \end{cases} ; \quad (x,y) \in \mathcal{D}$$

where

$$F^i(x,y) = \frac{2B^i/C^i(d_0)}{(2\pi)^{3/2}\sigma_u^i \ln 10} \frac{\exp\left\{-\frac{1}{2\sigma_u^{i\,2}}\left(B^i \log_{10} d^i(x,y) - z^i + A^i\right)^2\right\}}{[d^i(x,y)]^4} \cdot \left[\frac{B^i\left(B^i \log_{10} d^i(x,y) - z^i + A^i\right)}{2\sigma_u^{i\,2} \ln 10} - 1\right]$$

22. A method as claimed in any preceding claim, wherein a location estimate is provided using an algorithm solving the following equation in x and y:

$$\begin{cases} \sum_{i=1}^{N}\left[-\frac{\mathcal{I}_i}{|\mathbf{R}|}(x-x^i)-\frac{(\widetilde{\mathcal{I}}_i-1)}{|\mathbf{R}|}\left\{(x^i)^2x-x^iy^i(y-y^i)\right\}\right]=0 \\ \sum_{i=1}^{N}\left[-\frac{\mathcal{I}_i}{|\mathbf{R}|}(y-y^i)-\frac{(\widetilde{\mathcal{I}}_i-1)}{|\mathbf{R}|}\left\{(y^i)^2y-x^iy^i(x-x^i)\right\}\right]=0 \end{cases} \quad ; \quad (x,y)\in\mathcal{D}$$

23. A method as claimed in any preceding claim, wherein a location estimate is provided using an algorithm based on the following equation:

$$\hat{x}=\frac{\sum_{i=1}^{N}\frac{x^i}{\mathcal{I}_{i0}}}{\sum_{i=1}^{N}\frac{1}{\mathcal{I}_{i0}}} \quad ; \quad \hat{y}=\frac{\sum_{i=1}^{N}\frac{y^i}{\mathcal{I}_{i0}}}{\sum_{i=1}^{N}\frac{1}{\mathcal{I}_{i0}}} \quad ; \quad (\hat{x},\hat{y})\in\mathcal{D}$$

24. A method as claimed in any preceding claim, wherein said location estimate is provided by one of a iterative and a closed form method.

25. A method as claimed in any preceding claim, wherein said location estimate is provided by one of a linear and non linear method.

26. A system for estimating the location of a mobile device, comprising:

means for collecting location information;

means for selecting at least one of a plurality of different location methods to provide a location estimate said methods using cell identity information; and

means for providing a location estimate based on the at least one selected location method, wherein said at least one location method comprises using cell identity.